

Inverse Design Workshop preparation

Download workshop materials at:

<https://kx.lumerical.com/t/lumerical-and-siepicfab-inverse-design-workshops/34471>

Ensure you download and install the latest version of FDTD Solutions from

<https://www.lumerical.com/downloads/customer/>

Necessary if you want to perform layout of your final design for submission to SiEPIC

- Install Klayout (<http://www.klayout.de/build.html>)
- Install the SiEPIC Ebeam PDK by following the instructions at https://github.com/lukasc-ubc/SiEPIC_EBeam_PDK/wiki/Installation-instructions

Lumerical's Suite of Tools

DEVICE Suite

Multiphysics

FDTD Electromagnetics

MODE Waveguide Component Design

DGTD Finite Element Electromagnetics

FEEM Eigenmode Analysis

CHARGE Charge Transport

HEAT Heat Transport

STACK Optical Stack Analysis

SYSTEM Suite

System & Circuit

INTERCONNECT PIC Simulation

CML Compiler Automated CML Generation

System Element Library Extension

Laser Element Library Extension

Verilog-A Runtime API

Partner Interoperability

Automation API Python Integration

Foundry Resources

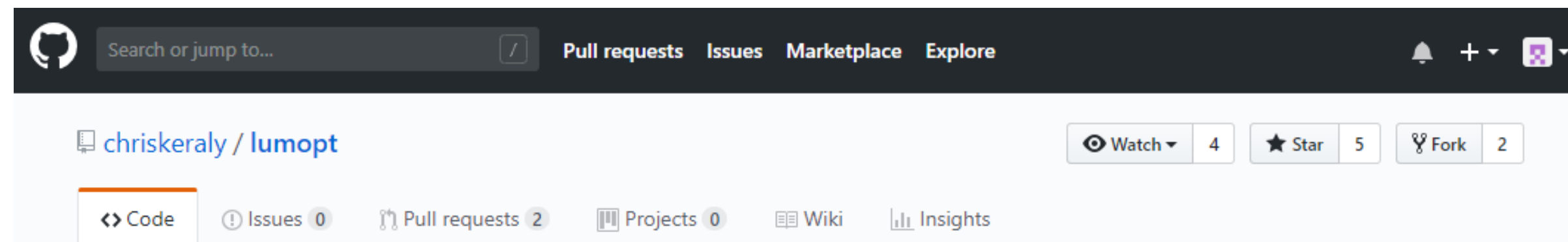
INTEROPERABILITY, AUTOMATION & FOUNDRY SUPPORT

Interfaces

Lumopt: Python Based Inverse Design for Lumerical FDTD

- Lumopt: open source implementation of the adjoint method
- Collaboration with Lumerical over past year
- Targets integrated photonics
- Uses FDTD Solutions for simulation
- Uses Lumerical Automation API
- Now included with FDTD Solutions

<https://github.com/chriskerally/lumopt>



Python based continuous adjoint optimization wrapper for Lumerical

Adjoint shape optimization applied to electromagnetic design

Christopher M. Lalau-Keraly,^{1,*} Samarth Bhargava,¹ Owen D. Miller,²
and Eli Yablonovitch¹

¹Department of Electrical Engineering and Computer Sciences, University of California at Berkeley, Berkeley, California 94720, USA

²Department of Mathematics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA
^{*}chrisker@eecs.berkeley.edu

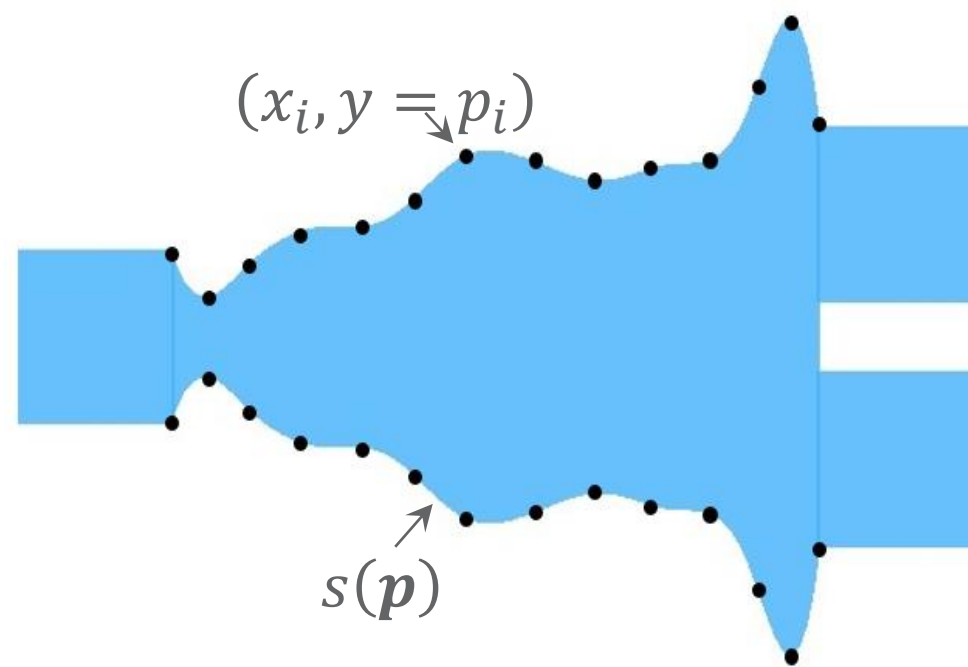
Optics Express, Vol 21, Issue 18, 2013

<https://www.osapublishing.org/oe/abstract.cfm?uri=oe-21-18-21693>

Parametric Shape based adjoint optimization

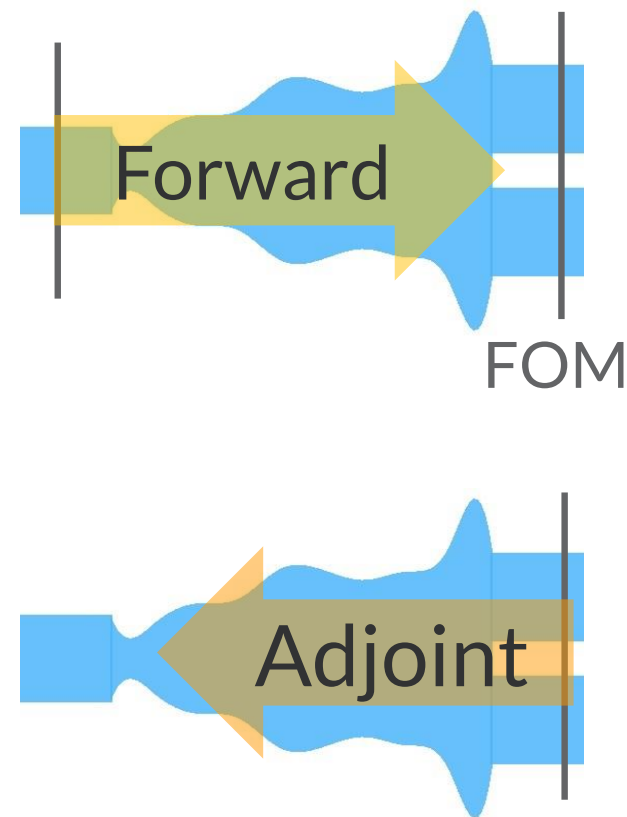
Parametric shape

- Defines design space
- Optimization parameters



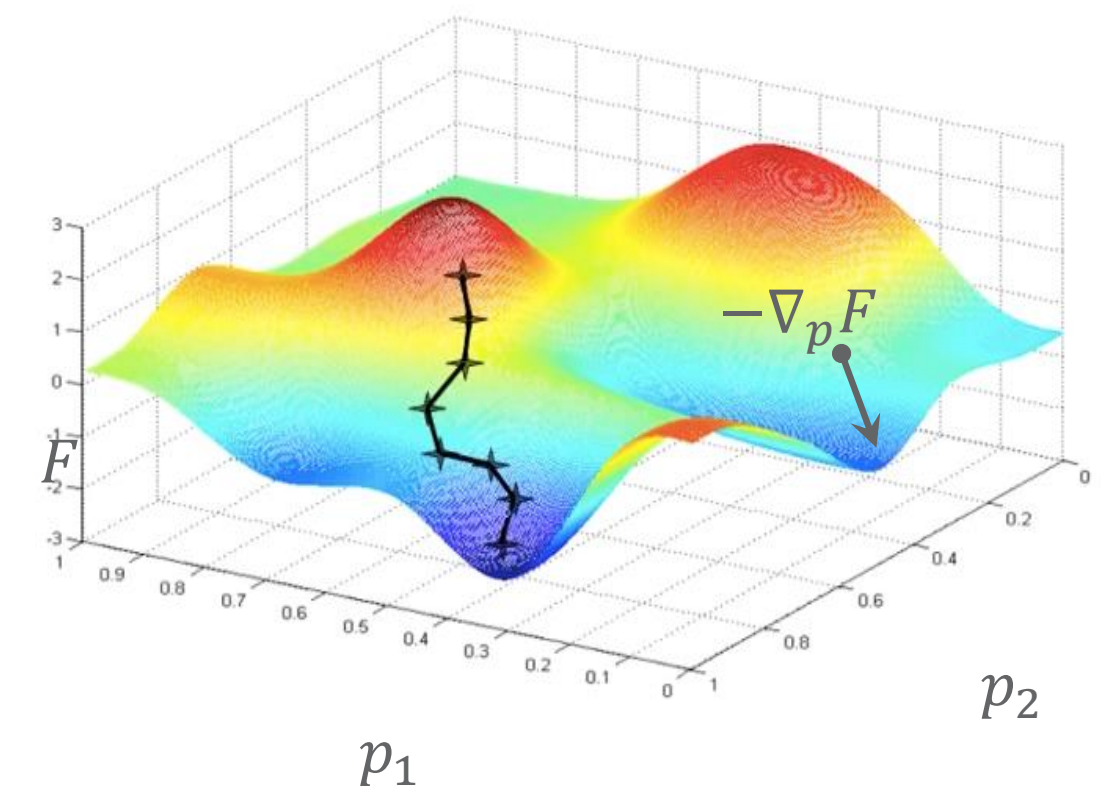
Adjoint sensitivity analysis

- Efficiently compute gradient
- **2 FDTD simulations**
- **Independent of # parameters**



Gradient based optimization

- Highly efficient optimization
- Uses more physics of device



<https://hackernoon.com/gradient-descent-aynk-7cbe95a778da>

Workshop outline

The challenge

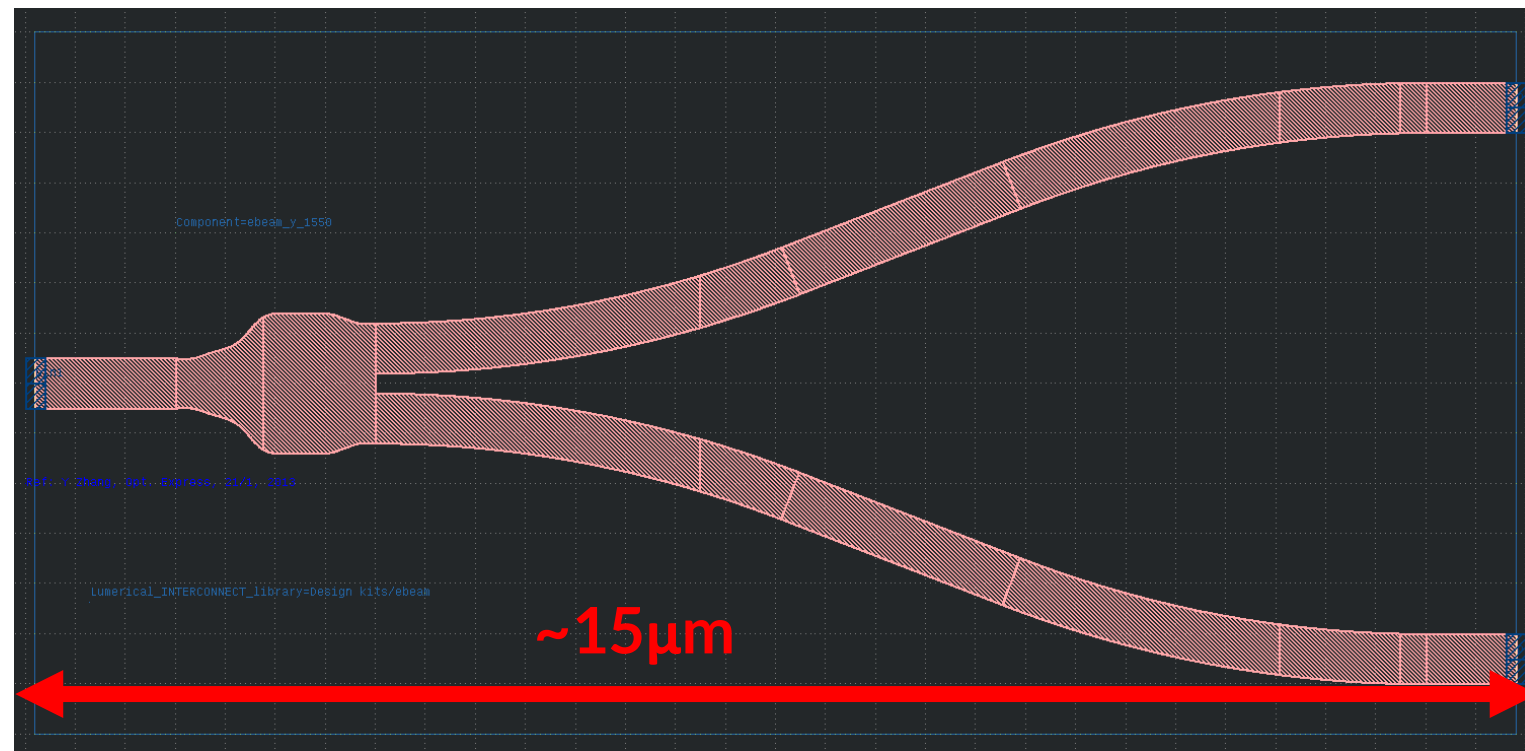
- Constraints
- Options you can change
- The figure of merit to determine the winner

Steps:

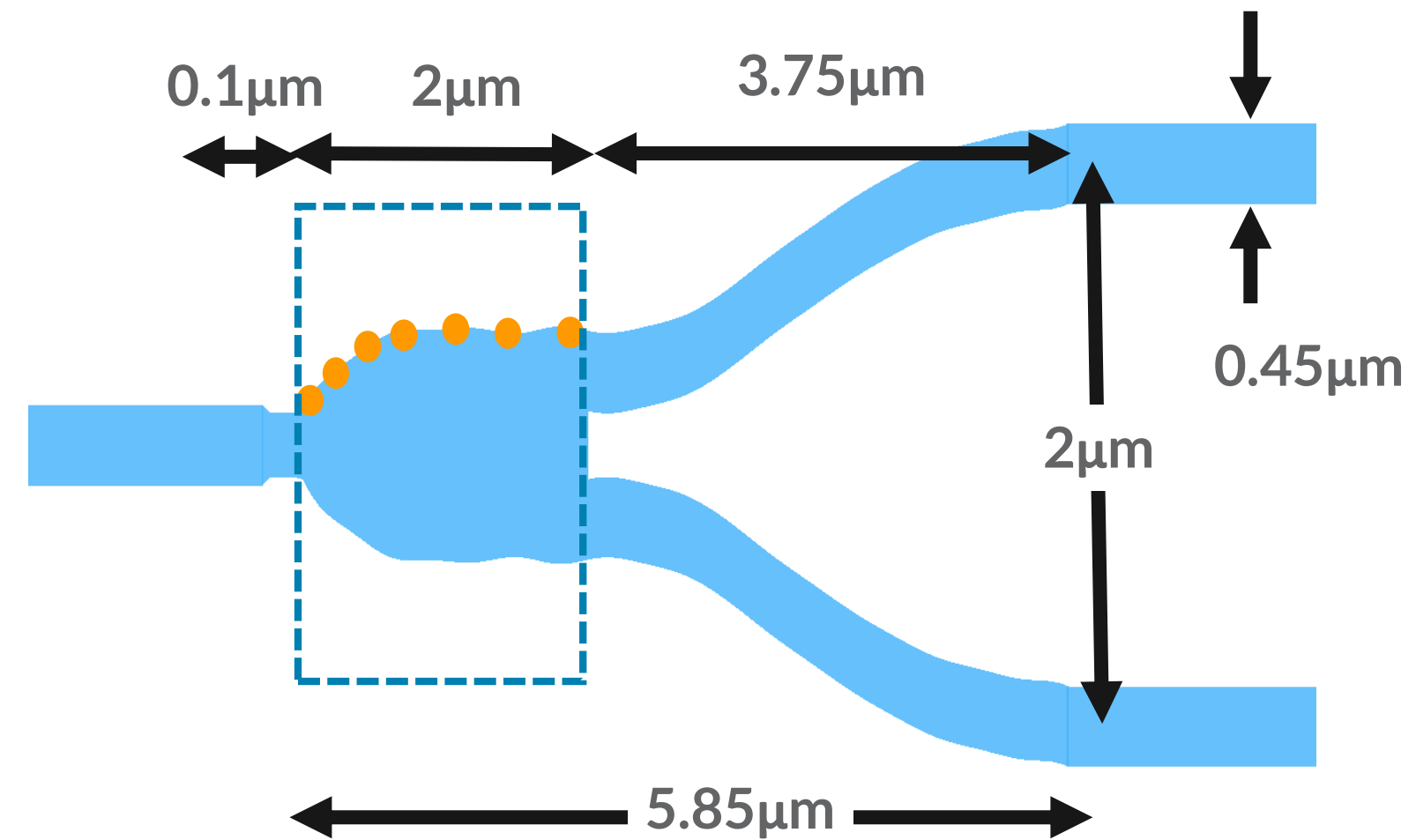
- Review constraints
- Make your design choices
- Start running optimization
- Generate 3D results and extract S parameters
- Generate full test layout by running Python script we've prepared with Klayout
- Inspect the full layout

The challenge

- Can we make a smaller splitter?
- Can we ensure broadband operation?



- Parametric shape with output waveguides



https://github.com/lukasc-ubc/SiEPIC_EBeam_PDK

A compact and low loss Y-junction for submicron silicon waveguide

Yi Zhang, et al, Optics Express Vol. 21, Issue 1, pp. 1310-1316 (2013)

Design choices

Number of control points for the spline = number of optimization parameters

- Currently set to 10

Spline boundary condition

- 'clamped' or 'not-a-knot' – currently 'clamped' which means derivative is 0 at boundaries

Bandwidth

- Currently set to C+L band

Delta (for robust design)

- If $\delta=0$ we do normal optimization
- If $\delta \neq 0$ (see next slide)
- Currently $\delta = 20\text{nm}$

Note that adjoint optimization is a steepest descent method

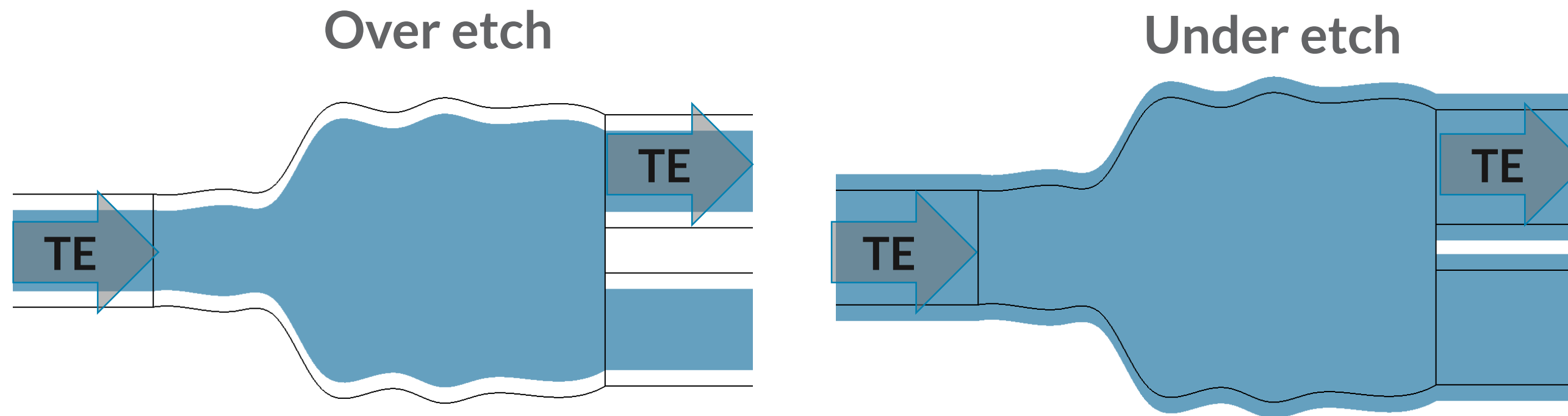
- Adding more constraints can actually smoothen the FOM landscape and allow you to avoid local minima BUT too many constraints will reduce the FOM

What does delta do?

If delta is not zero, we do co-optimization

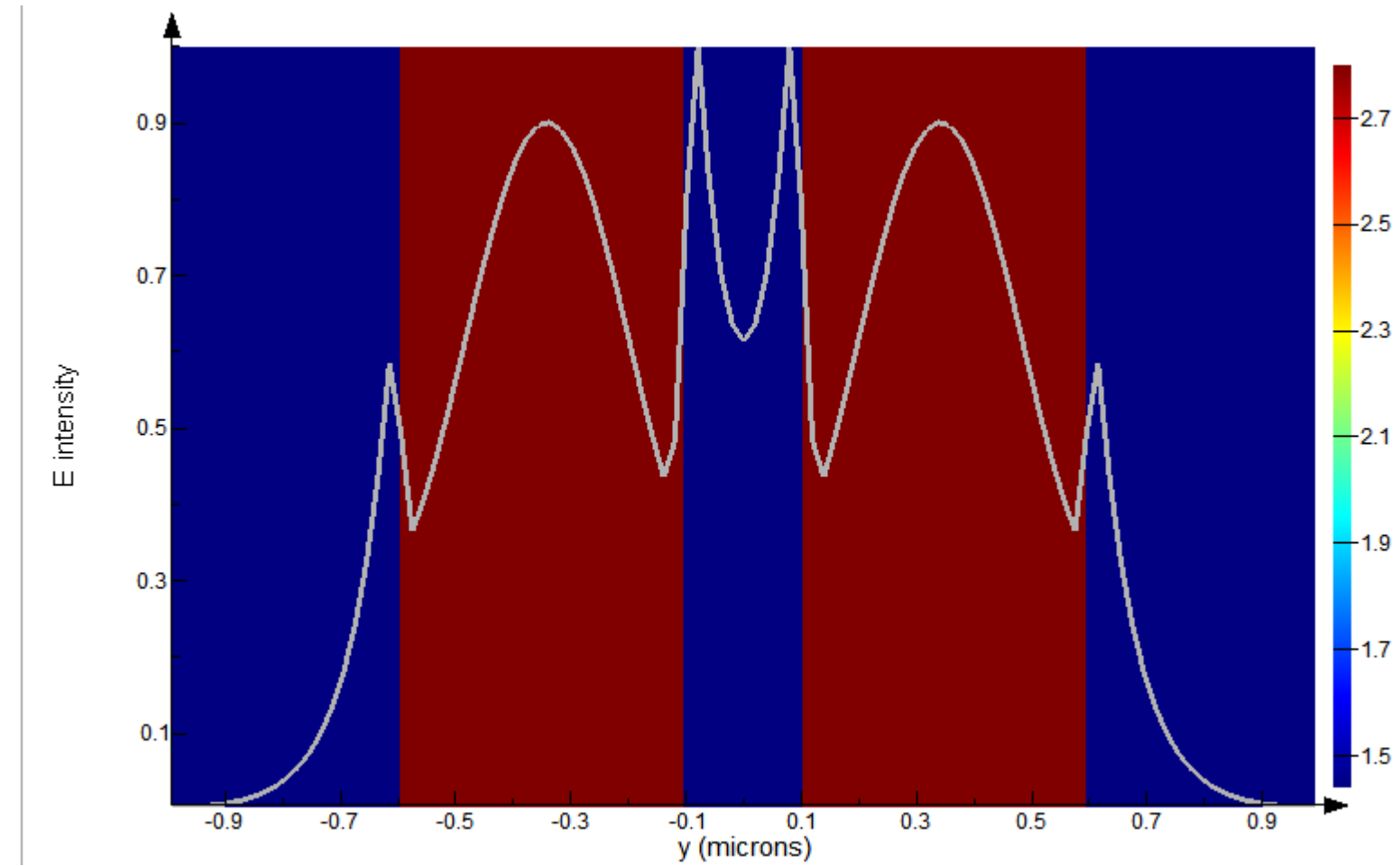
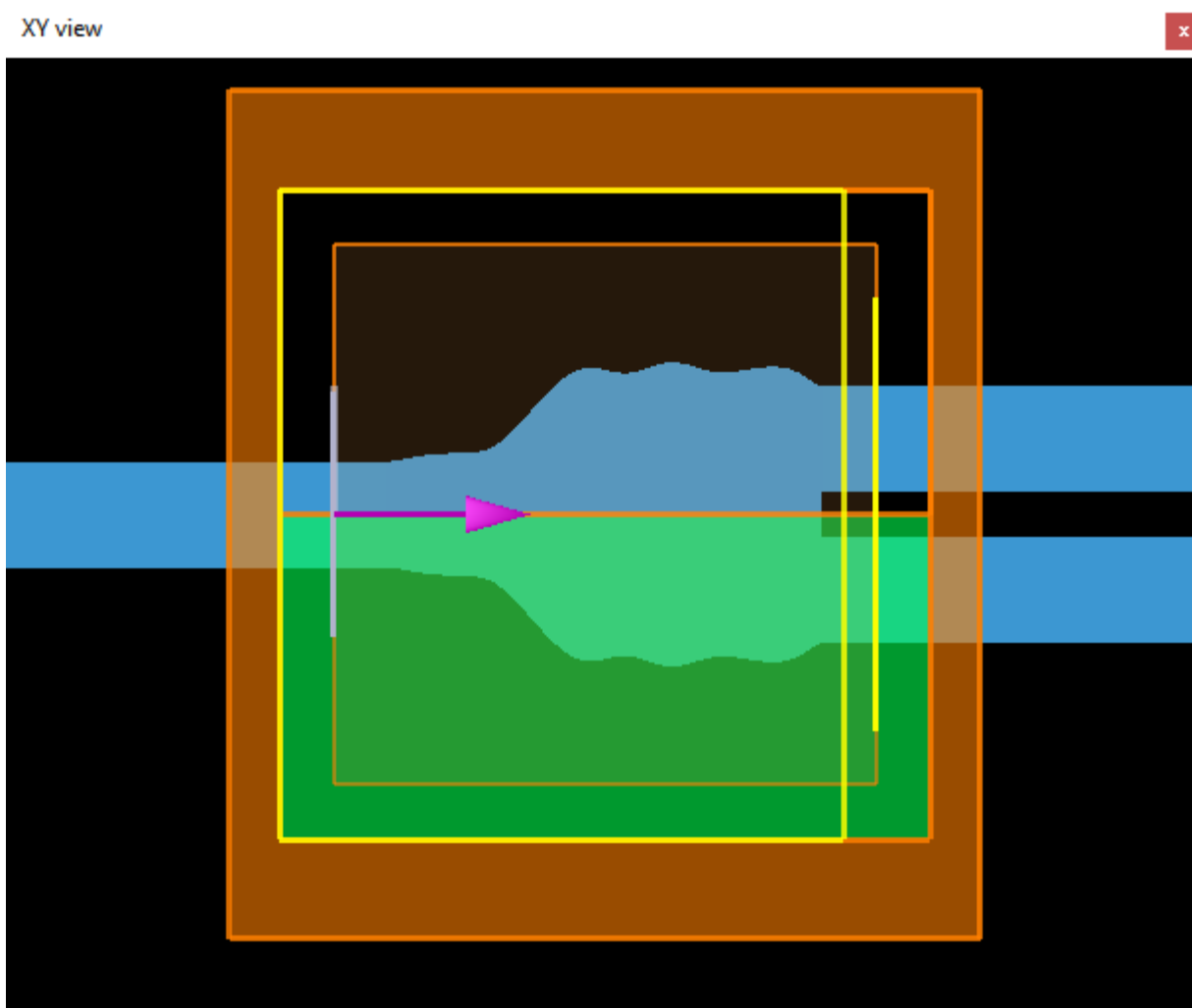
- “Over etch” slightly smaller than nominal (-delta)
- “Under etch” slightly larger than nominal (+delta)

FOM = sum of FOMs from both simulations



What FOM are we optimizing?

FOM is the power transmitted to the symmetric waveguide mode

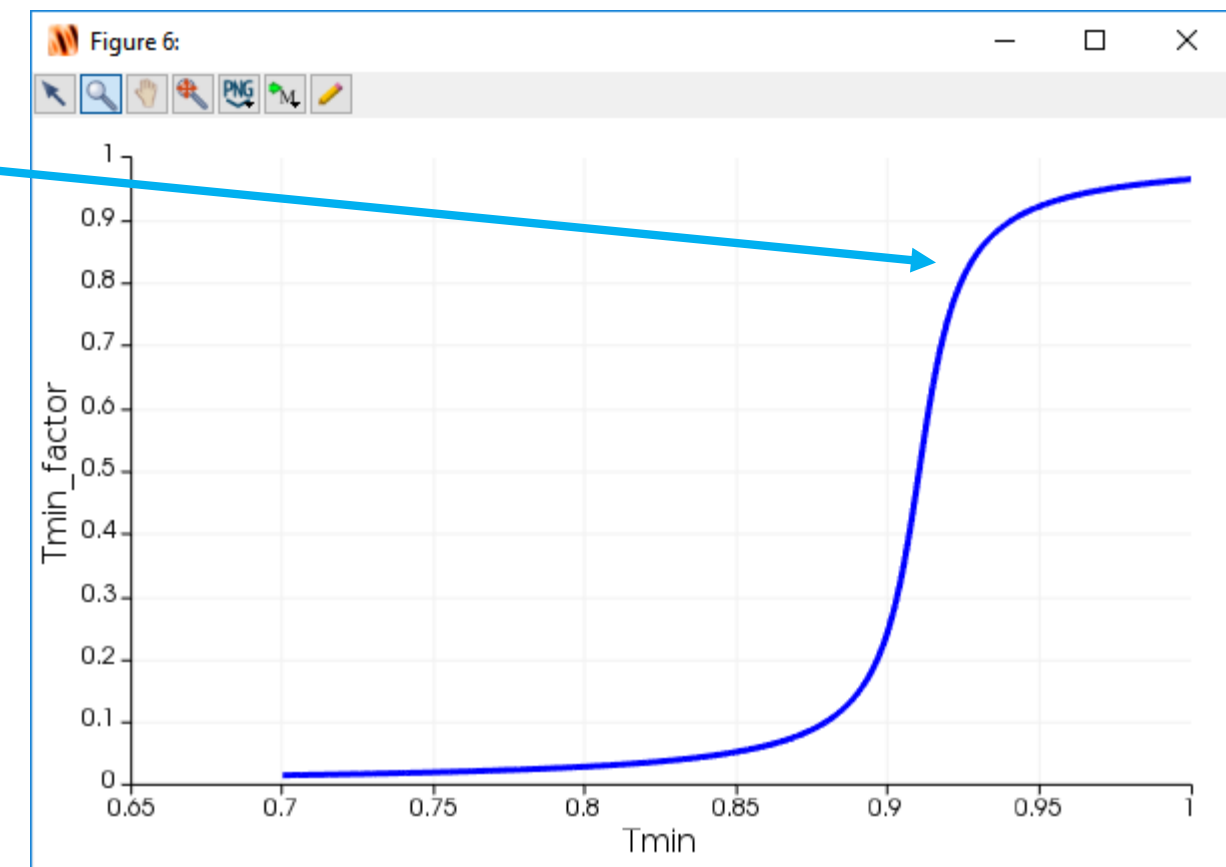


How do we judge the workshop winning design?

From 3D simulation including bent waveguide arms we extract the S matrix for the nominal design (no over-etch/under-etch)

The best design has the highest **design_score** where:

- $\text{design_score} = \text{Tmin_factor} * \text{bandwidth_factor}$
- $\text{Tmin_factor} = \text{atan}(100 * (\text{Tmin} - 0.91)) / \pi + 0.5$
- $\text{bandwidth_factor} = \text{bandwidth} / 100\text{nm}$
- **Tmin** is the minimum transmission over the bandwidth



There is a big cost to allowing your minimum transmission to fall below about 0.3 dB !

Running the examples in FDTD Solutions

Method 1: Easy

1. Open FDTD Solutions
2. Open .py file in FDTD script editor
3. Press run script

Method 2: Power user

1. Install Python, SciPy, Jupyter
2. Configure Python path to Lumerical modules in <FDTD folder>/api/python
3. Open *.ipynb in Jupyter

Uses Python and Lumopt provided with FDTD Solutions

Requires FDTD Solutions 2019a R6 (8.21.1933)
Software installer available on USB drive or web
Windows: <http://lumeri.ca/zeqxy>
MacOS: <http://lumeri.ca/7d952>

Windows



Mac



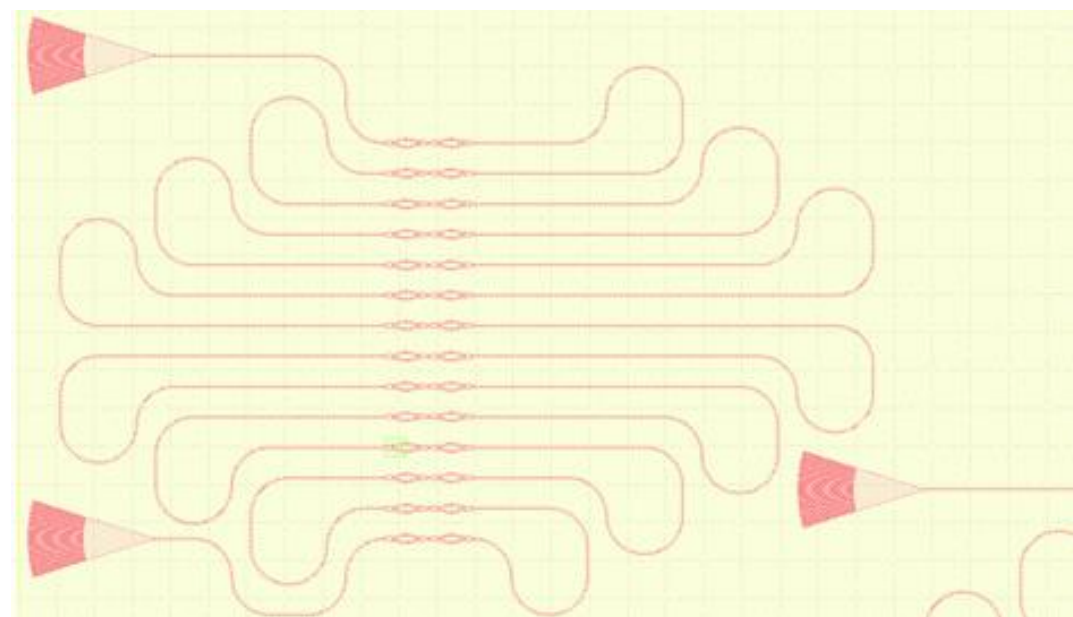
Making the full test layout

We provide a scripts called `make_test_layout.lsf` and `make_test_layout.py`

Run by

- Open `make_test_layout.lsf` and press run
 - You may need to edit the script depending on your Klayout installation folder
- Power users
 - Opening a command prompt and change to the directory where you are working
 - Run `<KLayout install folder>\klayout_app.exe -r make_test_layout.py`

Inspect with KLayout



Submit your design

See https://www.linkedin.com/pulse/openabl-fabrication-test-passive-silicon-photonic-lukas-chrostowski?trk=portfolio_article-card_title

Key points

- Submission:
 - Filename – openEBL_USERNAME.gds – “openEBL” is case sensitive; replace USERNAME with your name. Append “_A”, “_B”, etc., if submitting multiple layouts.
 - Top cell – openEBL_USERNAME
 - Upload your GDS layout file here: <https://bit.ly/2M4hPPT> The secret is the material that the waveguides are made of (hint: chemical element with atomic number 14)
- Merge verification
 - Download the following files, to check that your design is here and correct. There may be a 1-5 minute delay between submission and merge.
 - Merged GDS file: <http://upload.siepic.ubc.ca/openEBL/openEBL.gds>
 - Log file: <http://upload.siepic.ubc.ca/openEBL/openEBL.txt>
 - Automated measurement coordinate list: http://upload.siepic.ubc.ca/openEBL/openEBL_coords.txt
- Fabrication results:
 - Will be shared via Dropbox.com: <http://bit.ly/1fiQe7I> and <https://www.dropbox.com/sh/030suvs0vk4pw66/AABDah85xHeMPgyARms73pCda?dl=0>. To download a particular folder, replace the =0 with =1.

Disclaimer: Nothing is guaranteed. Provided as-is, best effort. The designs submitted here are publicly accessible. For educational purposes. Space limited; first-come first-served.

Next steps

Lukas Chrostowski's edX course!

The screenshot shows the edX course page for "Silicon Photonics Design, Fabrication and Data Analysis" by Lukas Chrostowski. The page features a navigation bar with links for Courses, How It Works, Schools & Partners, and About. A search bar and the user's name "LukasChrostowski" are also visible. The main content area includes a video player thumbnail, the course title, a description, and a green "You Are Enrolled" button. Below this, there is a section for "About this course" with a 5-star rating and a "See more" link. A "What you'll learn" section lists four topics: Optical modelling tools, Mask layout tools, Design of optical devices and circuits, and Data analysis techniques. On the right, a sidebar provides course details: Length (7 weeks), Effort (3-25 hours/week), Type (Professional Education), Price (\$495), Institution (UBCx), Subject (Engineering), Level (Intermediate), and Languages (English). The footer includes logos for NSERC CRSNG, UBC, and Si-EPIC CREATE, along with the copyright notice "© 2017 L. Chrostowski" and the page number "3".

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Starts on April 5, 2016

You Are Enrolled

UBC a place of mind THE UNIVERSITY OF BRITISH COLUMBIA

About this course

18 Reviews 5/5 ★★★★★

This short course teaches students and industry professionals how to design integrated optical devices and circuits, using a hands-on approach with commercial tools. We will fabricate your designs using a state-of-the-art (\$5M) silicon photonic rapid-prototyping 100 keV electron-beam lithography facility. We will measure your designs using an automated optical probe station and provide you the

[+ See more](#)

What you'll learn

- Optical modelling tools
- Mask layout tools
- Design of optical devices and circuits
- Data analysis techniques

🕒 Length:	7 weeks
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🗨️ Languages:	English

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